MASTER OF SCIENCE
IN
MECHANICAL ENGINEERING

UNIFORM FLOW PAST A RIGID SPHERE BY THE SPECTRAL NUMERICAL METHODS

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A steady, axially symmetric, incompressible, viscous flow past a rigid sphere is numerically simulated by using a numerical scheme, based on spectral methods. The equations have been reduced to two sets of nonlinear second order partial differential equations in terms of vorticity and stream function. The calculations have been carried out for Reynolds numbers, based on the sphere diameter, in the range 0.1 to 104.

The numerical results have verified that there is excellent agreement with Stokes theory at very low Reynolds numbers. At moderate to intermediate Reynolds numbers there is good general agreement with available experimental data and flow visualization pictures. The Reynolds number at which separation occurs is estimated as 20. The approach to boundary-layer behavior with increasing Reynolds numbers is also verified by comparison with potential flow theory and analytical boundary-layer solution.

FAULT ASSESSMENT OF A DIESEL ENGINE USING VIBRATION MEASUREMENTS AND ADVANCED SIGNAL PROCESSING

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A Diesel Engine test cell was developed, which consisted of a Detroit Diesel 3-53 engine, a water brake dynamometer and an engine cycle analyzer. Extensive steady state and time resolved instrumentation were installed along with a high speed data acquisition system to obtain cylinder pressure and engine vibration data. High frequency response accelerometers were mounted on the cylinder head assembly to measure phase resolved response relative to top dead center (TDC) on the first cylinder. Baseline vibration data were taken over a range of engine load and speed combinations. An engine fault was introduced by adjusting the timing on the first cylinder injector. The vibration signatures of the baseline engine and the induced fault engine were characterized using Joint Time Frequency Analysis. The fault condition was detected and localized.

LINEAR STRUCTURAL STRESS ANALYSIS OF A HULL GIRDER PENETRATION AND A SHORT LONGITUDINAL BULKHEAD USING FINITE ELEMENT MODELING

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The objective of this study is to investigate structural shadow zones encountered in shipbuilding design using the Integrated Design Engineering Analysis Software (IDEAS). The term "shadow zone" refers to areas of low stress concentrations that are caused by lines of stress bending around structural discontinuities. Two ship design situations frequently encountered that result in shadow zones are hull girder penetrations and short structural longitudinal bulkheads. In both of these situations, a long-used rule of thumb is to construct a line with a slope of 1:4 originating from the discontinuity that encompasses the area of low stress. The material within this line is then considered ineffective when computing the section modulus. This can prove to be expensive. However, powerful finite element analysis software is readily available that can analyze the shadow zones in greater detail and possibly minimize the area considered ineffective. This study uses the I-DEAS™ software to develop finite element models of the cited design situations for a U.S. Navy Frigate, FFG-7 class of ship. It conducts a static structural linear analysis of the ship balanced on a trochoidal wave of height $1.1\sqrt{L}$. The results generated in this study validate the rule of thumb in both situations.

AIRCRAFT WAKE VORTICES AND FIELD DATA

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Trailing vortices shed from large aircraft pose great danger to following aircraft in cruise, landing, and take-off conditions. Too much separation time reduces the effective use of airports and increases cost and pollution, while too little separation poses grave dangers. The accurate determination of the optimal separation time between the leading and following aircraft in a landing corridor became a major international concern. The LIDAR data, obtained by the Lincoln/MIT laboratories at various airports, have been used to analyze in as much detail as possible the velocity, core radii, circulation, vorticity, and the decay mechanisms of trailing vortices.

ROLL STABILIZATION FOR T-AGOS CLASS SHIPS

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The T-AGOS class 3 and 4 ships are under consideration by the United States Air Force for use as sea-based radar platforms. In order to meet mission requirements, their roll motion must be reduced. Several roll damping methods appropriate for this class of ships are considered. Bilge keel stabilization is studied in more detail and various sized bilge keels are analyzed, utilizing a seakeeping prediction program, for the full range of ship speed and sea states. Operability indices at several roll angles and for various bilge keel shapes are developed and compared. Design considerations based on the above studies are made.

FIRE MODELING FOR COOK-OFF IN ORDNANCE MAGAZINES

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In this study, the time temperature profile of a missile exposed to fire in a compartment adjacent to the missile magazine is examined. The study required the development of a heat transfer model based on the geometry and thermophysical properties of a new concept for a vertical launching system, the Concentric Canister Launcher (CCL). Different fire scenarios are analyzed by the model to predict the time it takes to reach a critical value or “cook-off” temperature of the missile’s propellant and explosives.

CALCULATION OF TARGET MASKING EFFECTS FOR AIR-TO-SURFACE ORDNANCE DELIVERY

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The Perspective View Generator (PVG) is a database driven simulation that displays a three-dimensional synthetic environment from terrain information stored in a two-dimensional array. Each terrain element is identified by coordinates which index the array. Each array value contains 32 bits of information arranged to specify the greyshade, elevation, and other features of the terrain at that position. Currently there are few areas of the world digitally mapped in the data format accepted by the PVG.

The objective of this thesis is to enable the automatic generation of a database for use with the PVG from information available from various sources. The project involves writing computer algorithms to synthesize data from different sources and making modifications to the PVG functions. The source of terrain information is aerial imagery and elevation information which is not resolved fine enough to distinguish tree and building heights. The ability to modify the data base to include object heights allows the PVG to show the target masking effects these objects have in a given region. The resulting synthetic environment can be used for strike planning and as a mission tailored training tool.

AN INVESTIGATION INTO THE DAMAGED STABILITY OF A TUMBLEHOME HULL WARSHIP DESIGN

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The objective of this study is to investigate the hydrostatics and damaged stability of a tumblehome hull form by comparing the tumblehome form with one of similar displacement and geometric properties in a wallsided hull form. The data for the comparison is generated by modeling the hull forms in a computer modeling program designed by Creative Systems Incorporated titled General HydroStatics. The objective was achieved by conducting research and computer modeling in 3 parts: 1) model development, 2) intact stability analysis, and 3) damaged stability analysis. This thesis demonstrates both the intact stability and damaged stability problems that will be encountered if the tumblehome hull design is used on a modern warship, as well as the benefits from using an innovative and modern tumblehome hull design.

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TIME AND FREQUENCY DOMAIN SYNTHESIS IN THE OPTIMAL DESIGN OF SHOCK AND VIBRATION ISOLATION FOR LARGE STRUCTURAL SYSTEMS

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The dynamic analysis of large, complex structural systems is computationally intensive and therefore prohibits the use of optimization procedures, which are both iterative and complex with respect to variable search patterns. The solution to this problem is through the use of time and frequency synthesis techniques. They provide a means of rapidly recalculating a system's changed response due to structural modifications, as dictated by the optimization procedure. The efficiency is gained through the fact that the synthesis methods are independent of model size, in that only those model degrees of freedom where changes are made are required in the analysis. Furthermore, these methods are exact in their formulation, including the treatment of non-proportional damping. These structural synthesis techniques are developed in the context of optimal design of shock and vibration isolation systems. Their utility and value is demonstrated in the optimal design of an isolation system for a 109 dof non-proportionally damped structural system. In the course of the optimization, the synthesis techniques make possible 80 transient, frequency response, and static analyses in 2 hours and 39 minutes (desktop computer), while yielding an isolation design which satisfies all design constraints.

CREEP BEHAVIOR OF THE INTERFACE REGION IN CONTINUOUS FIBER REINFORCED METAL-MATRIX COMPOSITES

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The accurate incorporation of interface effects on creep in metal matrix composites is contingent on the direct experimental determination of the deformation kinetics. An experimental approach is identified that is capable of providing the necessary data regarding interface deformation without being influenced by the other mechanisms in the composite. The goal is accomplished by isolating the composite interface and precisely measuring the creep characteristics of the interface, by utilizing a fiber-pushout apparatus to apply a constant force on the fiber of a model single fiber composite (SFC), so that the interface can creep under the applied shear stress. Two different model fiber-matrix systems—one with no mutual solubility and the other with limited mutual solubility—were investigated. In both systems, the interface displayed Bingham flow (diffusional flow with a threshold stress). The Finite Element Method (FEM) was utilized to check the conceptual validity of the test approach for one of the model systems, and to provide insight into the design of the sample and test apparatus. FEM was also utilized to estimate the residual radial stresses present in the model composite system following cooling from an elevated to ambient temperature. Based on the experimental results and the FEM analysis, an analytical model is advanced to incorporate the effect of radial residual stresses on the creep of the fiber-matrix interface. The model yields an explicit constitutive law which describes the stress, temperature, and matrix property dependence of interfacial creep. The model also indicates that the experimentally observed threshold stress is directly attributable to the normal (radial stress) acting on the fiber-matrix interface.

AN INVESTIGATION INTO THE IMPACTS OF ADDING AN AUTOMATED DAMAGE CONTROL SYSTEM TO A COAST GUARD 270' WMEC CUTTER

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This investigation studied the ship impacts of adding an automated damage control system to a Coast Guard vessel. The available new technology may allow better damage control systems to be utilized aboard Coast Guard vessels, with potential accompanying manning reductions. This study attempts to quantify some of the expected changes in parameters and how they may be applied to other new ship designs.

This study was carried out in three distinct parts: 1) A technology assessment of existing and proven damage control technologies for possible use on future Coast Guard vessels was conducted. Systems available commercially or through the U.S. Navy were included. Long term R&D efforts were excluded from this study. 2) A preliminary automated damage control system design was completed. The design used a Total Ship System Engineering design approach. The Coast Guard 270' Medium Endurance Cutter was the baseline platform utilized. The new design was compared to the existing baseline ship to investigate and determine the ship parameters impacted. Specifically, the parameters monitored were displacement, interior volume, cost, electrical load and manning levels. 3) Conclusions, concerning the potential value of an automated damage control system aboard ships, were drawn and are presented in this report.

FINITE ELEMENT MODELING AND SIMULATION OF THERMOMECHANICAL PROCESSING OF PARTICLE REINFORCED METAL MATRIX COMPOSITES

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During the consolidation phase, reinforcement particles of Metal Matrix Composites (MMC's) tend to be non uniformly distributed. The result is that the material properties of the composite materials are not as good as those originally desired. Through large amounts of straining, homogeneity can be achieved. Finite element models of MMC's undergoing different thermomechanical processes (TMP's) to true strains of approximately 1.2 were generated. The models consist of particle clusters within the particle-depleted matrix. The particle clusters were modeled by either a smeared model in which the particles refine the grains in the cluster, or a discrete model of the particles within clusters. The smeared and discrete models qualitatively agreed with each other. The results suggest that the best TMP to reach a state of reinforcement particle homogeneity was a hot worked, low strain rate TMP.

THE EFFECTS OF TITANIUM ON THE MECHANICAL PROPERTIES OF SHIELDED METAL ARC WELDING (SMAW) OF C-MN STEELS

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The strength and toughness of low alloy steel shielded metal arc weld (SMAW) metal is markedly improved by the presence of the microconstituent acicular ferrite. Since acicular ferrite is nucleated by the non-metallic inclusions present in the weld metal its presence is determined by the size, number, distribution, and chemical composition of these inclusions. Previous work has shown that inclusions containing no titanium are usually ineffective as nucleants of acicular ferrite in some C-Mn

steel weld metal whereas inclusions containing small amounts (less than 5%) of titanium or more can produce a microstructure containing as much as 70% of acicular ferrite.

In the present work the size, number, distribution and chemistry of the inclusions in two C-Mn steel weld metals containing 1 and 28 ppm respectively of Ti were studied by scanning and transmission electron microscopy, energy dispersive x-ray (EDX) analysis and parallel electron energy loss spectroscopy (PEELS). This work showed that the inclusions in the 'Ti-free' sample contained rhodonite ($MnO.SiO_2$) sometimes complexed with copper sulfide (CuS). In the sample that contained 28 ppm Ti the nature of the inclusions was found to be far more complex, often containing three phases. However EDX and PEELS analyses indicated that the titanium adopts a valency of 4 and may be complexed as pyrophanite ($MnO.TiO_2$) and the presence of this compound seems to be responsible for the nucleation of acicular ferrite although the exact mechanism is not yet clear. This work shows that it is important to control the Ti content of steel weld metal so that strong tough microstructures are produced; this issue is obviously of critical importance in Naval ship construction.

DEVELOPMENT OF AN ON-LINE FAILURE MODE DETECTION AND RESOLUTION ALGORITHM FOR THE *PHOENIX* AUV

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It has become apparent that in order for an AUV to be a more reliable self-sufficient system, it must have on-line failure detection and resolution capability. In support of this the AUV must have reconfigurable systems so as to be able to take corrective action against resolvable failures. A simulator has been designed using SIMULINK in order to analyze failure modes associated with the NPS *Phoenix* AUV steering system. The analyses of these failure modes have been used to identify possible signals for steering system fault detection. Finally, a rule based algorithm was developed which can be converted into a format that ultimately could be implemented in a fuzzy logic set, for later insertion into the *Phoenix* tactical level software. This methodology will be applied to the Navy's UUV.

THE EFFECT OF WATER TEMPERATURE ON UNDERBEAD CRACKING OF UNDERWATER WET WELDMENTS

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Specifications for underwater welding have not yet addressed the effect of water temperature on weldment microstructure. The environmental effects on underwater wet welding using a shielded metal arc welding (SMAW) process are severe with higher quenching rates, porosity, stag inclusions and diffusible hydrogen levels.

One of the problems associated with these high quenching rates and high diffusible hydrogen levels is the increased likelihood of underbead cracking in the heat affected zone (HAZ), particularly with steel weldments which have a higher carbon equivalent (approximately greater than 0.3). In this work, the underbead cracking resulting in three underwater test welds made on ASTM 516 grade 70 steel at three different water temperatures (2.8°C, 10°C and 31°C) was investigated. This was done by optical and scanning electron microscopy (SEM) and by making microhardness measurements.

HAZ underbead cracking was observed in all three weldments, but was much less prevalent in the 31°C sample and could only be seen at high magnifications in the optical microscope. The cracking in this weldment only appeared to occur in isolated regions where bead tempering had been ineffective for some reason. The weldments made at 10°C and 2.8°C both showed extensive evidence of underbead HAZ cracking typical of that associated with rapid cooling rates, high diffusible hydrogen levels and hard microstructures. SEM studies of the surfaces of these cracks showed evidence for transgranular failure with secondary cracking, both of which are typical of hydrogen induced cracking.

This work highlights the importance of water temperature, quenching and diffusible hydrogen levels in underwater wet welding. This is an issue of critical importance in the future wet welding structural repair of Naval ships.

STABILITY ANALYSIS OF SHIP STEERING IN CANALS

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The problem of ship steering in canals and confined waters is analyzed with emphasis on stability and bifurcation analysis. The classical maneuvering equations of motion augmented with a model for ship/canal interaction are used to model the open loop dynamics. Coupling of a control law and a guidance scheme with appropriate time lags is employed to model the essential dynamics of a helmsman. The complete system is analyzed using both linear and nonlinear techniques in order to assess its stability under finite disturbances. The results indicate that for certain regions of parameters, limit cycle oscillations may develop which could compromise system stability and safety of operations.

METALLIZATION OF CVD DIAMOND USING METAL OXIDE INTERMEDIATE LAYERS FOR ELECTRONICS PACKAGING

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The high thermal conductivity of chemically vapor deposited CVD diamond (up to 2000 W/m/K) and its low dielectric constant (~5.6) makes it highly desirable for use as an electronics packaging substrate material. To make CVD diamond amenable to thick film metallization via standard industrial processes, a thin γ-alumina layer (~1500Å) was grown on diamond by reactive evaporation of Al in oxygen over a very thin Cr intermediate-layer (~700Å). Commercially available silver and gold thick films were applied to CVD diamond both with and without the metal-oxide inter-layer. The interfaces were characterized by scanning electron microscopy, energy dispersive x-ray spectroscopy, Auger electron spectroscopy and transmission electron microscopy. The intermediate oxide layer was found to result in well-adherent, chemically bonded interfaces between the metallization and the CVD diamond substrates for both Ag and Au pastes. Without the oxide layer, the Ag paste was found to have very poor adhesion to the substrate. The Au paste, developed for non-oxide substrates, was found to be nominally adherent to the CVDD substrate, although quantitative adhesion comparisons between the metallization with and without the oxide inter-layer was not obtained. Micro structural and chemical characterization studies of the interface suggests that the alumina layer enhances adhesion by producing chemically reacted/solid solution species across all interfaces and is therefore a very versatile approach for thick film metallization of CVDD.

THERMAL BOUNDARY RESISTANCE IN A HIGH TEMPERATURE THIN-FILM SUPERCONDUCTOR UNDER VARYING HEAT FLUX

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The thermal boundary resistance between a $YBa_2Cu_3O_7$ thin-film and an MgO substrate was measured under conditions of varying heat flux. Heat flux was varied in a manner to explore any hysteresis effects present. It was concluded that hysteresis effects are present and are most likely attributed to changes in the peeling or compressive stresses in the thin-film. The changes in the peeling stresses may not be fully relieved after cycling of the heat flux or may have caused microstructural changes near the interface resulting in changes in microscale heat transfer characteristics. Additionally, the finite difference method was used to model the physical situation. It was found that boundary resistance values generated by the computer program were several orders of magnitude less than experimental values. It was concluded that finer meshes must be used

in order to increase the accuracy of the results. It was recommended that the modeling be redone on a main frame computer using finite element methods.

MICROSTRUCTURE, COMPOSITION, AND CRYSTALLOGRAPHY OF AALBROG LION BRAND DANISH WHITE CEMENT

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The morphology and crystallography of fully hardened Aalbrog Lion Brand Danish White cement paste (water to cement ratio 0.25) were examined using x-ray diffraction, optical and scanning electron microscopy with energy dispersive x-ray analysis (EDX) and transmission electron microscopy and EDX. These experiments showed the hardened cement to be mostly comprised of equiaxed particles of $3CaO.SiO_2$ with diameter of the order of 10 μm and larger often surrounded by inner and outer hydrated regions of an amorphous gel-like matrix with an average composition of about $1.75CaO.SiO_2.3H_2O$ (C-S-H) in which the CaO/SiO_2 ratio varied from about 0.3 $5 \rightarrow 5.74$. The hydrated regions were also found to contain significant amounts of $Ca(OH)_2$. Small amounts of ettringite $(Ca_6Al_2(SO_4,SiO_4,CO_3)_3(OH)_{12}.26H_2O)$ were also detected. In addition, selected area electron diffraction of the C-S-H matrix revealed diffuse rings, indicating the presence of short range ordering. The morphology of C-S-H matrix was found to be comprised of small "cells" of size approximately 5nm which are no doubt responsible for the good mechanical properties of this particular hardened cement paste. These results were also found to be in excellent agreement with previous research on this topic.

DEVELOPMENT, CORRELATION, AND UPDATING OF A FINITE ELEMENT MODEL OF THE OH-6A HELICOPTER

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This thesis is part of the helicopter research program established at the Naval Postgraduate School (NPS). NPS currently has two OH-6A light observation helicopters which were obtained from the U.S. Army. One of these is dedicated to ground vibration testing and dynamics research.

Previous research on the OH-6A at NPS established baseline vibration test data. The data includes natural frequencies, principal mode shapes and damping characteristics. This thesis continues previous research of the OH-6A and develops a detailed finite element model to be used in future helicopter dynamics research at NPS.

The model is based on an MSC/NASTRAN finite element model of a similar aircraft obtained from the McDonnell Douglas Helicopter Company. Both the nose and empennage were modified to represent the structural characteristics of the test article. Due to lack of structural design data, model mass updating was performed using previously obtained test data and a design sensitivity approach. The updated model natural frequencies agree well with the test data.

INSTANTANEOUS AXIS OF ROTATION FOR CONTINUOUS HUMAN KNEE MOTION

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Previous studies of human knee motion are based on finite rotation data collected using large rotation steps varying from 5 to 30 degrees. In some cases this rotation data is used to develop axes of rotation for the joint. For such analysis, the rotation axis developed may be significantly different from the joint's instantaneous axis of rotation because, in general, the axis of rotation developed using finite rotation steps only closely approximates the true instantaneous axis of rotation if the step size is small. For the current study, a device has been developed to record high frequency (15 Hz) rotation and translation data of the femur and tibia during knee flexion. Kinematic constraint equations have been developed to analyze the six degree of freedom rotation and translation data to obtain an accurate approximation to the instantaneous axis of rotation. Four cadaveric knees were analyzed with all ligaments intact. Motion characteristics common to all knees were identified. The most obvious characteristic, internal tibial rotation, was related to the initial varus/valgus orientation of each knee. The anterior cruciate ligaments (ACL) of these same knees were subsequently severed, the knees were measured, and the motion analyzed. Differences in the motion characteristics of each knee were detected after the ACL was cut.

EXPERIMENTAL PERFORMANCE STUDIES OF A PLATE HEAT EXCHANGER

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A plate and frame heat exchanger experimental test stand was developed. Using this test stand a performance analysis was conducted. The analysis consisted of evaluating the performance of the heat exchanger at varying flow rates and inlet temperatures, to develop an effectiveness-NTU and Log Mean Temperature Difference relationships, under steady state operation. The measured heat rates were compared to the heat rates provided by the manufacturer and good/bad agreement was found. Standard operating procedures for the test stand were developed and implemented.

PARAMETRIC PREDICTION OF THE TRANSVERSE DYNAMIC STABILITY OF SHIPS

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There currently exists no direct method for predicting the righting energy of a ship based on key geometric hull properties. Consequently, naval architects traditionally select hull parameters based on other constraints and merely check the dynamic stability indicators after designing the preliminary body plan. Quantifying these relationships would allow such indicators to be used as design variables in optimizing a hull form. Additionally, the hull form has a considerable impact on ship motion theory and dynamic stability criteria. This thesis suggests possible functional relationships, to predict the residuary stability of a design using basic hull parameters.

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A DISCRETE, DIGITAL FILTER FOR FORWARD PREDICTION OF SEAWAY ELEVATION RESPONSE

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The Autonomous Underwater Vehicle (AUV) must be able to operate in various shallow water sea-state conditions. In order to have a precise navigation and steering system, and efficiently place charges on underwater mines, the AUV must be able to sense and overcome hydrodynamic forces which are caused by waves. This thesis establishes a model of sea-state conditions based on spectral analysis, and uses the model to predict future knowledge of the sea. This prediction is determined by the random white noise output of a discrete, digital filter. The development of the discrete, digital filter is described herein. The Pierson-Moskowitz (P-M) spectrum which models seaway elevations using linear wave theory is used as a target spectrum which the filter will track. Cross-correlation between the P-M target spectrum and digital filter have shown that a reasonably accurate estimate of wave elevations can be predicted one full wave period into the future.

EXPERIMENTAL STUDY OF OSCILLATORY FLOW FORCES ON SMOOTH CIRCULAR CYLINDERS IN A PRESSURIZED ACOUSTIC CHAMBER

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This thesis investigates the measurement of forces on a smooth cylinder in a zero-mean oscillatory flow. The cylinder is representative of the leg of an offshore structure or platform, while the oscillatory flow is representative of the wave loading on such a structure. An acoustic standing wave, created by a piston oscillator provides a method to study such forces. The test cylinder is positioned across the diameter of a pressure vessel which is completely sealed to allow increased mean pressures and, therefore, lower viscosity and higher Reynolds numbers typical of such flows. Preliminary experiments using test cylinders from 0.6 to 1.5 inches in diameter and mean pressures up to 7.8 atmospheres were conducted to obtain force coefficients for small KC values and a wide range of 3 values. Higher harmonic forces and phasing were also measured and analyzed. This method of experimentation appears to have promising potential in evaluating high KC and high Reynolds number oscillatory flow force coefficients and to study the interaction of higher harmonic forces with marine structures. This work would find application in the consideration of wind and sea loads of offshore structures, moored vessels, cable runs, and risers.

ASYNCHRONOUS DATA FUSION FOR AUV NAVIGATION USING EXTENDED KALMAN FILTERING

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A truly autonomous vehicle must be able to determine its global position in the absence of external transmitting devices. This requires the optimal integration of all available organic vehicle attitude sensors. This thesis investigates the extended Kalman filtering method to merge asynchronous heading, heading rate, velocity, and DGPS information to produce a single state vector. Different complexities of Kalman filters, with biases and currents, are investigated with data from Florida's Atlantic Ocean Voyager II surface run. This thesis used a simulated loss of DGPS data to represent the vehicles submergence. All levels of complexity of the Kalman filters are shown to be much more accurate then the basic dead reckoning solution commonly used aboard autonomous underwater vehicles.

NONLINEAR ANALYSIS OF COUPLED ROLL/SWAY/YAW STABILITY CHARACTERISTICS OF SUBMERSIBLE VEHICLES

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The problem of coupled roll, sway, and yaw stability analysis of submersible vehicles is analyzed, with particular emphasis on nonlinear studies. Previous results had indicated that a primary loss of stability is through the development of limit cycles. This loss of stability is due to the coupling of roll into sway and yaw and cannot be predicted by considering the uncoupled dynamics. In this study, it is shown that the mechanism of loss of stability is through bifurcations to periodic solutions. These are characterized as either subcritical or supercritical, depending on the sign of a certain nonlinear coefficient. Implications of these results to vehicle performance and operations are discussed.

VISUALIZING TRANSIENT STRUCTURAL RESPONSE BY EXPANDING SPATIALLY INCOMPLETE TIME HISTORY DATA

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Due to a limited number of accelerometers available for use, the shock trial for the DDG-51 class destroyer provided a spatially incomplete set of time history data. However, a visualization of the shock response of the entire ship is desired. To this end, finite element model reduction methods are employed to provide a transformation matrix which is used to expand this relatively small collection of data into the same number of degrees of freedom as the finite element model. Using this expanded set of time histories, it is possible to animate the transient response of the structure as a whole. This approach is investigated using computer-simulated transient response data from a finite element model of a flat plate. The use of static and dynamic reduction methods are explored in the creation of the transformation matrices required for the visualization of the expanded data. The animations are assessed based on a quantitative comparison with the full-order transient model response.

NUMERICAL SIMULATION OF FLOW INDUCED BY A SPINNING SPHERE USING SPECTRAL METHODS

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A direct numerical simulation, based on spectral methods, has been used to investigate viscous, incompressible, steady, rotationally symmetric flow due to a sphere rotating with a constant angular velocity about a diameter. The equations of motion have been reduced to a set of three nonlinear second order partial differential equations in terms of the vorticity, the stream function and the azimuthal velocity. The calculations have been carried out for Reynolds numbers (Re) from the Stokes flow regime (low Re) to the boundary layer regime (high Re).

The numerical results clearly show how the Stokes flow behavior for low Reynolds numbers, and the boundary layer behavior for high Reynolds numbers, are approached in the appropriate limits. Besides showing the flow streamlines, results have been presented for the torque and the skin friction behavior. It is shown that the present results are in excellent agreement with both available experimental data, and previously obtained numerical data. The radial equatorial jet which develops with increasing Reynolds numbers has been observed as expected from boundary layer collision behavior. No separation was observed for the range of Reynolds numbers considered, even near the equator.